Structural Identification of Nonlinear Static Objects

Power Function

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Abstract

The problem of structural identification of static plants with a vectorial input which contain single-valued nonlinearities, is considered. For a problem solution passage in special structural space is fulfilled. The method of construction of space is described. The criterion of an estimation of degree of linearity of plant is introduced. Algorithms of decision-making on a class of nonlinearity on the basis of a method of secants and construction of area which belong to nonlinearity are offered. Results of modelling are reduced.

Keywords

Identification; Structure; Secant; Decision-making; Nonlinearity; Static Object

Introduction

Various approaches and methods have been applied to identification of nonlinear static systems. In [Raybman and Chadeev; Ljung; Graupe] the statistical methods based on the correlation and dispersive analysis are used. Adaptive methods of identification are considered in [Karabutov (2)]. In identification systems genetic and neuronet algorithms [Norgaard, Ravn, Poulsen and Hansen; Madár, Abonyi and Szeifert] and their combinations with various methods of approximation [Righeto, Grassi and Pereira; Sato] have been applied. In [Masri, Caffrey, Caughey and Smyth; Aguirre, Barroso, Saldanha and Mendes] a priori information and the subsequent approximation on the set class of functions are presented [Graupe; Espinoza, Suykens and De Moor]. For approximation of nonlinear systems in [Billings and Hua-Liang Wei] new classes of the wavelet functions minimizing number of estimated parameters are employed. Thus the choice of a class of functions has not yet been proved.

Difficulties in structural identification of static objects are explained as following factors:

i) the system exit is the integrated size reflecting influence of set input variables;

ii) absence of the methods, making the allocation of necessary interrelations “input-output” for classification of a form of nonlinearity. Approaches to an estimation of degree of nonlinearity of system are stated in [Raybman and Chadeev; Ljung]. The solution to the problem of an estimation of degree of nonlinearity is a key to a choice of a class of nonlinear static models. It is based on application of complex mathematical apparatus and approaches to structural identification are absent;

iii) attempts of a priori task of nonlinear structure [Graupe; Mosteller] on a set of existing inputs in application of the parametrical approach demands the problem permission collinearity (multicollinearity) [Johnston; Draper and Smith]. The problem is complex, bat its decision simple which is defined by conditions of practical realization of models. This simple decision (exception of dependent variables) is applied widely in real control systems. But such approach does not allow solving a problem of structural identification. Unfortunately, such interrelation is not always understood and in existing methods practically is not considered;

iiii) application of parametrical methods on the set class of polynoms [Graupe; Ivachnenko and Muller]. Efficiency of such approach depends on experience and intuition of the researcher. It demands performance of preliminary labour-consuming researches. Such approach does not allow defining nonlinearity structure in an explicit form. Wide application of parametrical methods in problems of structural identification explain their simplicity, which in the given specific area fails to give effective results.

Consideration on specified difficulties, in [Karabutov

(4)] the methodology of structural identification of nonlinear static systems with a vector input in the conditions of uncertainty is offered. Systems contain single-digit and multiple-value nonlinearity. In [Karabutov (3)] the method of structural identification of nonlinear static systems on a class single-digit nonlinearities (CADN) with a vector input is available. Algorithms of decision-making on an accessory of a nonlinear part of system power, logarithmic or exponential functions are developed. For logarithmic function the special class of transformation of an input is provided. On its basis the algorithm of decision-making on nonlinearity structure is developed. The decision is accepted in special structural space [Karabutov (4)]. In this space properties of some nonlinear mapping are analysed. The approach to structural identification of systems about the CADN and the vector input, offered in [Karabutov (4)], makes a multicollinearity problem ease [Mosteller].

In work on the basis of the results obtained from [Karabutov (3, 4)], development of the offered approach for static system with several single-digit nonlinear functions $f(u_i)$ is given. The criterion of an estimation of nonlinearity of object on a set of secants is provided. For nonlinear object, the decision is searched in structural space (SS). The method of construction of SS is acquired. Structures $S_{k,e}^{v}$ (virtual portraits) are put into a SS [Karabutov (1)] which reflect properties of a nonlinear part of object. Despite nonlinearity $S_{k,e}^{v}$, a decisions on structure $f(u_i)$ is accepted based on the analysis of linear functions γ (secants $S_{k,e}^{v}$). It is one of advantages of the offered approach to structural identification, which has two available methods of decision-making concerning structure $f(u_i)$ based on application of different criteria. The case of static object with nonlinearities belonging to a class of power functions is considered. Methods and algorithms of an estimation of structure of object are acquired provided that, the factor of determination of a secant of a virtual portrait should belong to some set limited area. The method of decision-making on function structure $f(u_i)$, proceeding to a condition of hit of a secant of a portrait $S_{k,e}^{v}$ in some sector of structural space is described. The method of restoration of nonlinear function in initial space of measurements is taken into account.

Problem Statement

Consider the object described by the equation

$$y_n = A^{\mathrm{T}}U_n + B^T f(U,n) + \xi_n, \qquad (1)$$

where $U_n \in R^k$, $y_n \in R$ are input and output an object; $u_{i,n} \in U_n$ is the limited irregular function possessing property limiting absence of degeneracy; $A \in \Omega_A \subset R^k$ is the vector of the parameters belonging to limited, but a priori to unknown area Ω_A ; $B \in R^m$; $n \in J_N = [0, N]$ is discrete time; $\xi_n \in R$ is an disturbance, $|\xi_n| < \infty$,

$$f(U,n) = \left[f_1(u_{p_1,n}), f_2(u_{p_2,n}), \dots f_m(u_{p_m,n}) \right]^T, \qquad (2)$$

$f_m(u_{i,n})$ is a limited single-digit function, $p_i \in [1,m]$.

For (1), (2) the information set is known

$$\mathrm{I}_o = \mathrm{I}_o(y,U) = \{y_n, U_n, \ n \in J_N = [0,N]\} \qquad (3)$$

and mapping corresponding to it

$$\Gamma_o : \{U_n\} \to \{y_n\} \ \ \forall n \in J_N,$$

describing an observable information portrait [Karabutov (4)].

It is necessary on the basis of the analysis (3) and Γ_o to estimate structure of function $f(U,n)$.

Further object (1), (2) we will name system as S_f.

Approach to Structural Identification

The method of an estimation of structure in a nonlinear part (2) systems S_f in the conditions of uncertainty is based on application of the approach, offered in [Karabutov (3)]. We will reduce search of the decision to realization of some steps. The first step is to estimate the degree of linearity of system and then the theorem 1 of [Karabutov (3)] is applied. If the decision on nonlinearity of system is true, work in the special structure (portrait) $S_{k,e}^{v}$, reflects a state of a nonlinear part of system of identification. In work [Karabutov (3)] $f(U,n)$ there is the single-digit nonlinear function depending on one independent variable. Application of these results here can appear incorrect. In particular, a decision-making can be inefficient a decision-making on the basis of one criterion.

Two approaches are available to an estimation of structure of function $f(U,n)$. The choice of methods of identification of structure appreciably depends on a nonlinearity class. More low we will consider a case, when $f(u_{i,n})$ belong to the class of power functions

$$f_i(u_{i,n}) \in \mathcal{F} = \left\{u_{i,n} \in R : u_{i,n}^{\alpha_i}\ \forall n \in J_N, \alpha_i < \infty\right\}.$$

The first approach is based on a choice of structure of a secant γ for a virtual portrait $\mathcal{S}_{k,e}^{v}$. Parameter α of secant γ can be defined so that, to provide a factor of determination [Mosteller and Tukey] γ of some set area.

We also reduce the second approach to a choice of parameter α of function $f(u_{i,n}) \in \mathcal{F}$. Thus we should assure belonging of a secant γ to structure $\mathcal{S}_{k,e}^{v}$ to some set in special structural space. This set we will name sector.

Estimation of Degree of Linearity Object

Consider restriction of an observable information portrait $\Gamma_o^{u_i} \subset \Gamma_o\big|_{u_i \in U}\ \forall i = \overline{1,k}$. For $\Gamma_o^{u_i}$ construct a secant

$$\overline{\gamma}(y, u_i) = a_{0,i} + a_{1,i}u_{i,n} \tag{4}$$

by means of a least-squares method, where $a_{0,i}$, $a_{1,i}$ are some real numbers. Define a secant $\overline{\gamma}(y, f_l)$ for $f_l = f(u_{l,n}) \in \mathcal{F}$, $l < k$.

Define set of secants

$$\overline{\Gamma}(U, y) = \{\overline{\gamma}(y, u_i),\ \overline{\gamma}(y, f_l),\ i = \overline{1,k},\ l \geq 1\},$$

set on I_o.

Consider set on (3) subset of secants for

$$\mathrm{S}(U, y) \subset \overline{\Gamma}(U, y),$$

which we name a field of secants $\mathcal{S}_S = \mathrm{S}(U, y)$ of system S_f.

Designate $\Phi_n \triangleq [\overline{\gamma}(y_n, u_{1,n})\ \overline{\gamma}(y_n, u_{2,n}) \ldots \overline{\gamma}(y_n, u_{k,n})]^T$. Consider the equation

$$\hat{y}_n = \Psi^{\mathrm{T}}\Phi_n, \tag{5}$$

where a vector $\Psi \in R^k$ can be defined by means of a least-squares method. The vector estimation Ψ exists proceeding from above assumptions concerning an input U_n.

Structural completeness of system S_f in the field of structures $\mathcal{S}_S$ is defined based on the following statement [Karabutov (3)].

Theorem 1. Consider a vector of informative variables $U_n \in R^k$ and set of secants $\mathrm{S}(U, y)$ for Γ_o. Then the system (1) is linear, if

$$\chi = \sum_{i=1}^{m} \psi_i = 1, \tag{6}$$

where ψ_i is i-th element of a vector Ψ in (5).

The theorem 1 gives sufficient conditions of degree of linearity (nonlinearity) of system S_f on the set field of structures $\mathcal{S}_S$. If the condition (6) is true, that field $\mathcal{S}_S = \overline{\Gamma}(U, y)$ is full and $\mathcal{S}_S$ is a linear envelope of an output of system (1), (2). If (6) it is not true, value $\mathcal{N}_S = 1 - \chi$ be termed as an estimation of level of nonlinearity.

Let the condition (6) be exclusive from implementation. Hence, we have $\mathcal{S}_S \subset \overline{\Gamma}(U, y)$. Pass through an evaluation stage of structure of a nonlinear part of system.

Virtual Portrait for Decision-making on Nonlinearity Structure

Construct auxiliary set which contains the information on function $f(U, n)$ in (1) [Karabutov (4)]. Generate a variable $s_n = I^T U_n$, where $I \in R^k$ is an unit vector. Apply model $\hat{y}_{s,n} = \hat{a}_s s_n$. Define parameter $\hat{a}_s \in R$ from a condition

$$\arg\min_{\hat{a}_s}(\hat{y}_{s,n} - y_n)^2 = \hat{a}_s^*.$$

The variable $e_n = \hat{y}_{s,n} - y_n$ contains the data about nonlinear function $f(U, n)$. Generate set

$$\mathrm{I}_e = \{\ e_n, U_n,\ n \in N\}. \tag{7}$$

The set I_e reflects processes in a nonlinear part of object. Such method of construction I_e excludes domination of any input object.

Now we have reduced a problem to identification of structure of function $f(U, n)$ on set I_e. Apply the approach offered in [Karabutov (4)], to a choice of arguments of function $f(U, n)$. Choose such $u_{i,n}$, which gives the maximum value of factor of determination between e and u_i.

Mapping $\Gamma_e : \{u_{i,n}\} \to \{e_n\}$ does not allow solving a problem of structural identification of system S_f [Karabutov (4)]. Explain it to that $e_n \in R$ has irregular features and does not satisfy a condition of Geldera-Lipshitsa. Therefore for an estimation of structure of a nonlinear part S_f construct the mapping, adequately describing a state of system of identification on set (7). Apply the approach described in [Karabutov (1, 4)]. It is based on introduction of the variables, received as a

result of processing I_e.

Enter a coefficient of structural properties

$$k_{e,u_i,n} = k_s(e,u_i,n) = \frac{e_n}{u_{i,n}}.$$

On J_N arrange $k_{e,u_i,n}$ is increase. Generate set $\left\{ k_{i,q}^v \right\}$, where $k_{i,q}^v = k_s(e^v, u_i^v, q)$, $q \in J_N^v = [0, N]$. As to every $k_{i,q}^v$ corresponding value e_q^v, receive

$$\mathrm{I}_k^v = \left\{ e_q^v,\, k_{i,q}^v,\, q \in J_N^v \right\}.$$

Consider on I_k^v mapping $\Gamma_{e,k_i}^v : \left\{ k_{i,q}^v \right\} \to \left\{ e_q^v \right\}$ and structure $\mathcal{S}_{k_i,e}^v$ corresponding to it. $\mathcal{S}_{k_i,e}^v$ shows change of processes in nonlinear system of identification. Properties $\mathcal{S}_{k_i,e}^v$ are researched in [Karabutov (1, 4)]. The virtual structure $\mathcal{S}_{k_i,e}^v$ has universal characteristic for single-digit and multiple-valued nonlinearities.

The method identification of structure of object (1), (2) with one power nonlinearity $f(u_i)$ on the basis of the analysis $\mathcal{S}_{k_i,e}^v$ is described in [Karabutov (1, 4)]. In our case the offered approach demands updating. In particular, except the analysis of properties $\mathcal{S}_{k_i,e}^v$ it is necessary to develop special criteria for decision-making on structure $f(U,n)$.

Algorithms of Decision-making on Function Structure $f(U,n)$

Application of Method Secants

We will not consider algorithms of decision-making on a belonging $f(u_{i,n})$ to the set class of nonlinearities. This problem is researched in [Karabutov (3)]. We suppose that $f(u_{l,n}) \in \mathcal{F}$, $l \le m$.

Consider set

$$\mathrm{I}_k^v = \left\{ e_q^v,\, k_{i,q}^v,\, q \in J_N^v \right\}$$

it corresponds to the structure $\mathcal{S}_{k_i,e}^v$, described by mapping Γ_{e,k_i}^v. Construct for each structure $\mathcal{S}_{k_i,e}^v$ secant, described by a polynom of degree p

$$\overline{\gamma}_{i,p}\left(e^v, k_{i,q}^v\right) = \overline{\gamma}_{i,p} = a_{0,i} + \sum_{j=1}^{p} a_{1,j}\left(k_{i,q}^v\right)^j. \tag{8}$$

Order of a polynom (8) define so, that

$$\max_j r^2_{e^v\overline{\gamma}_{1,p}} \to p^*, \tag{9}$$

where $r^2_{e^v\overline{\gamma}_{i,p}}$ is a factor determination between e^v and k_i^v.

Let

$$\delta_*^2 = r^2_{e^v k_i^v}(p^*). \tag{10}$$

We will describe the approach to structural identification $f(u_{i,n}) \in \mathcal{F}$ with the task of border for change of factor of determination. Consider mapping

$$\Gamma_{e,k_i}^v(\alpha_i) : \left\{ k_{i,q}^v(\alpha_i) \right\} \to \left\{ e_q^v \right\}, \tag{11}$$

where $k_{i,q}^v(\alpha_i)$ is a coefficient of structural properties of system identification with an input $u_i^{\alpha_i}$, $\alpha_i < \infty$ is some number.

$\Gamma_{e,k_i}^v(\alpha_i)$ corresponds to structure $\mathcal{S}_{k_i,e}^v(\alpha_i)$ in space $\mathcal{P} = \left(k_i^v, e^v\right)$. We will name $\mathcal{P}$ structural space.

Construct for a $\mathcal{S}_{k_i,e}^v(\alpha_i)$ secant

$$\overline{\gamma}\left(e^v, k_{i,q}^v(\alpha_i)\right) = \overline{\gamma}_{\alpha_i} = a_{0,i} + a_{1,i} e^v, k_{i,q}^v(\alpha_i) \tag{12}$$

and define coefficient of determination $r^2_{e^v\overline{\gamma}_{\alpha_i}}$.

Theorem 2. Let for system S_f in space $\mathcal{P}$: i) the structure $\mathcal{S}_{k_i,e}^v$ and a secant $\overline{\gamma}_{i,p}\left(e^v, k_{i,q}^v\right)$ described by the equation (8) is constructed; ii) the order of a polynom (8) satisfies a condition (9); iii) the mapping (11) the description of structure $\mathcal{S}_{k_i,e}^v(\alpha_i)$ is set; iiii) for the $\mathcal{S}_{k_i,e}^v(\alpha_i)$ secant (12) is constructed and the factor determination is defined $r^2_{e^v\overline{\gamma}_{\alpha_1}}$. Then $f(u_{i,n})$ is an element of structure of system S_f, if the α_i function parameter $f(u_{i,n}) = u_i^{\alpha_i}$ is derived from a condition

$$\left| r^2_{e^v\overline{\gamma}_{\alpha_i}} - \delta_*^2 \right| \le \Delta_i,$$

where $\Delta_i \ge 0$ is some magnitude, δ_*^2 is derived from a condition (10).

The proof of the theorem 2 is based on application of the theorem 3.6 [Karabutov (4)].

Apply the theorem 2 to decision-making on function structure $f(u_{j,n})$, $j \le m$.

Thus, it is shown that, how on the basis of the analysis of virtual portraits $\mathcal{S}_{k_i,e}^v(\alpha_i)$, $\mathcal{S}_{k_i,e}^v$ to makes the decision on system structure S_f.

Remark. To check correctness of the received decisions the theorem 1 is applied.

Decision-making on the Basis of Sector Construction

The decision on $F(U,n)$ we can accept on the basis of construction of set (sector) $\mathrm{Sec}_{\alpha_i}(e)$, belongs to nonlinearity. The method of construction of sector for static systems is offered in [Karabutov (1)] and developed in [Karabutov (4)]. We will search for sector on a plane $\left(e^v, k_i^v\right)$ as area

$$\mathrm{Sec}_{\alpha_i}(e) = (\overline{\gamma}(e, k_{e,u_i}), \overline{\gamma}(e, k_{e,s_i,\alpha_i})),$$

limited to the specified straight lines. The area $\mathrm{Sec}_{\alpha_i}(e)$ should belongs to a secant $\overline{\gamma}_{\alpha_i}$ in space $\mathcal{P}$.

Describe a method of identification of a vector $F(U,n)$ on the basis of sector construction [Karabutov (4)].

Let the u_i condition be $r_{u_i e} \geq \delta_e$, where $\delta_e > 0$ some set size, is satisfied. Consider mapping $\Gamma_e \subset \{k_{e,u_i,n}\} \times \{e_n\}$ and its restrictions $\Gamma_e^{k_{e,u_i}}$ $\forall i = \overline{1,k}$. For every $\Gamma_e^{k_{e,u_i}}$ a secant is constructed

$$\overline{\gamma}(e, k_{e,u_i}) = \overline{\gamma}_i = a_{e,0}^i + a_{e,1}^i k_{e,u_i}. \tag{13}$$

Corresponding secants $\overline{\gamma}_{\alpha_i}$ (12) construct for mappings $\Gamma_e^{k_{e,u_j,\alpha_j}}$ $\forall u_j^{\alpha_j} \in \mathcal{F}$ $(j \geq 1)$.

Introduce set of secants

$$\overline{\Gamma}(K,e) = \{\overline{\Gamma}(K_e,e), \overline{\Gamma}(K_{e,\alpha},e)\} \quad \forall e_n \in \mathrm{I}_e,$$

where

$\overline{\Gamma}(K_e,e) = \left\{\overline{\gamma}(e,k_{e,u_i}),\ i = \overline{1,k}\right\}$, $K_e = \left[k_{e,u_1}, \ldots, k_{e,u_m}\right]^T$, $k_{e,u_i,\alpha_i} \in K_{e,\alpha}$, $K_{e,\alpha} \in R^m$, $m \leq k$, $\overline{\Gamma}(K_{e,\alpha},e) = \{\overline{\gamma}_{\alpha_j}\ \ j \geq 1\}$.

The bottom boundary of sector $\mathrm{Sec}_{\alpha_i}(e)$ is derived from the following statement.

Theorem 3 [Karabutov (4)]. Any secant $\overline{\gamma}(e,k_{e,u_i}) \in \overline{\Gamma}(K_e,e)$ at $j = i$ limits an element $\overline{\gamma}(e,k_{e,u_j,\alpha_j}) \in \overline{\Gamma}(K_{e,\alpha},e)$ from below.

On the basis of the set analysis $\overline{\Gamma}(K_e,e)$ it is impossible to define the upper border of sector $\mathrm{Sec}_{\alpha_i}(e)$.

Therefore the received field of structures are added to a secant $\overline{\gamma}(e,k_{e,s_i,d_i})$, where $s_i \in R$, $s_i = I^T(U \setminus u_i)$. Due to the upper border of area of sector $\mathrm{Sec}_{\alpha_i}(e)$ we can use a secant $\overline{\gamma}(e,k_{e,s_i,d_i})$ [Karabutov (4)], where $d_i < \infty$. The statement is true at least for $0 < d_i < 1$.

Statement. If $\overline{\gamma}(e,k_{e,u_i,\alpha_i}) \subseteq \mathrm{Sec}_{\alpha_i}(e)$, which is an $f(u_i) \in \mathcal{F}$ element of structure of system S_f.

The statement proof is based on application of the theorem 3.7 of [Karabutov (4)].

So, methods of structural identification of a nonlinear part considered are based on the analysis of virtual portraits of system identification in space $\mathcal{P}$. The basic advantage of virtual portraits $\mathcal{S}_{k,e}^v$ is possibility to apply methods analyzed on a class of linear functions.

Restoration of Initial Nonlinear Function of Object

Consider the problem on restoration of function $f(u_{i,n})$ on the basis of the above received results. Let the decision on structure be accepted as $f(u_{i,n}) \in \mathcal{F}$ and the set I_o being irregular character. Hence, function change $f(u_{i,n})$ also has irregular character. To receive a function form $f(u_{i,n})$ in the specified conditions on a plane $\left(u_i, f\right)$, the following actions are executed.

In space $\mathcal{P}$ define a secant $\overline{\gamma}_{\alpha_i}$ (12) for structure $\mathcal{S}_{k_i,e}^v\left(\alpha_i\right)$. Apply model (12) and make the prediction $\hat{e}_n^v$ of an output of system of identification e_n^v. Generate set

$$\mathrm{I}_k^v\left(\alpha_i\right) = \left\{ e_q^v,\ k_{i,q}^v\left(\alpha_i\right),\ q \in J_N^v \right\}.$$

On a basis $\mathrm{I}_k^v\left(\alpha_i\right)$ and (12) an ω_n estimation is received for $u_{i,n}^{\alpha_i}$

$$\omega_{i,n} = \frac{e_n^v - a_{0,i}}{\hat{e}_n^v}.$$

On a basis ω_n define an $\vartheta_{i,n}$ input estimation $u_{i,n}$. Arrange $\vartheta_{i,n}$ and $\omega_{i,n}$ on increase and receive a regular estimation of function $f(u_{i,n})$.

As $\omega_{i,n}$ calculated on the basis of the variable prediction e_n^v, the operation of preliminary processing of values $\omega_{i,n}$ is employed.

Example

Consider object (1), (2) with $A = \left[1.5; 2.5; 5\right]^T$, $B = \left[0.3; 0.3\right]^T$, $F(U) = \left[u_1^{0.4}; u_3^{0.6}\right]^T$. ξ_n is a stochastic

variable with a zero expectation and a final dispersion $|\xi_n| \leq 0.3$. Inputs $u_{1,n} \in U_n$ are normally distributed stochastic variables with a final expectation and a dispersion.

Estimation of degree of nonlinearity of object is defined by means of the theorem 1. Construct a field of secants $S_S = \mathrm{S}(U, y)$ and calculate a vector $\Psi \in R^3$ in (5) and χ: $\Psi = [0{,}339; 0{,}4; 0{,}29]^T$, $\chi = 1.03$. As $\chi \neq 1$, define $\mathcal{N}_S = 0.03$. The object is the nonlinear.

To structure identification $F(U)$ at first, a method of secants is utilized. Function $f(u_1) = u_1^{0.4}$ is also in consideration. For an estimation of structure function $f(u_1)$ generates set I_k^v and construct structure $S_{k_1,e}^v$, which is shown on Fig. 1. Receive for a $S_{k_1,e}^v$ secant $\bar{\gamma}_p$ (8). Results of modelling have shown that $p = 3$, and coefficient of determination (CD) $r_{e^v\bar{\gamma}_p}^2 = 0.985$. To a parameter choice α_1 in $f(u_1) = u_1^{\alpha_1}$ apply the theorem 2. Suppose $\Delta_1 = 0.0012$. Structure $S_{k_1,e}^v(\alpha_1)$ is shown on Fig. 1.

For a secant $\bar{\gamma}_1$ of a virtual portrait $S_{k_1,e}^v(\alpha_1)$ at $\alpha_1 = 0.4$ receive $r_{e^v k_1^v(\alpha_1)}^2 = 0.9862$. A parameter choice α_1 has been shown on Fig. 2. $\alpha_1 = 0.4$.

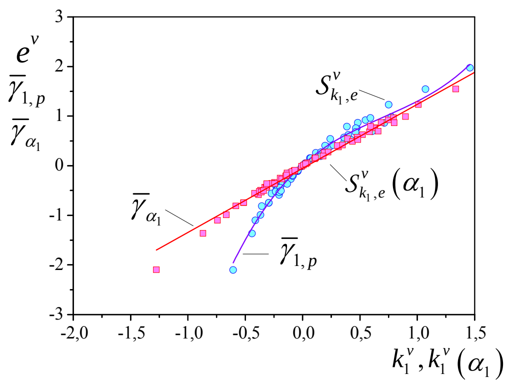

FIG. 1 ESTIMATION $f(u_1)$ BY MEANS OF SECANTS

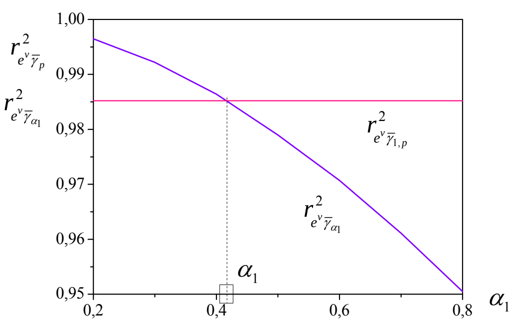

FIG. 2.CHOICE α_1

Compare structures $S_{k_1,e}^v$, $S_{k_1,e}^v(\alpha_1)$ (Fig. 1). The correct choice of an input gives structure straightening $S_{k_1,e}^v(\alpha_1)$. It speaks from adequacy of a choice of parameter α_1. From Fig. 2 the specified estimation has been acquired for α_1 which is equal to 0.42.

Similarly an estimation for α_3 function $f(u_3)$ has been defined. $\alpha_3 = 0.62$ (Fig. 3).

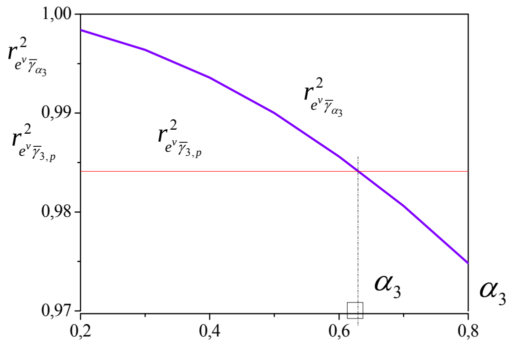

FIG. 3 CHOICE α_3

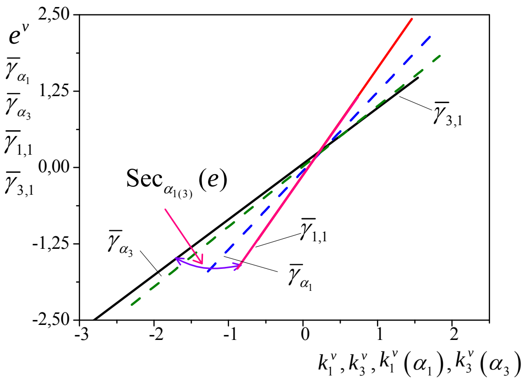

FIG. 4 SECTOR FOR $F(U)$

Example of construction of sector $\mathrm{Sec}_{\alpha_{1(3)}}(e)$ is shown on in Fig. 4 in which secants $\bar{\gamma}_{i,p}$ (8) are designated with $p = 1$. Function restoration $f(u_1)$ is shown in a Fig. 5.

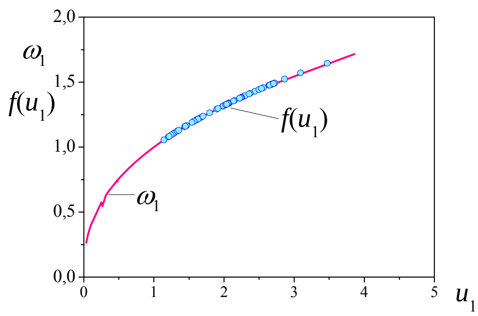

FIG. 5 RESTORED FUNCTION $f(u_i)$

Conclusions

The problem of structural identification of static objects with a vector input and several power nonlinearities in the conditions of uncertainty is considered. The method of an estimation of degree of nonlinearity of object on the basis of the analysis of completeness of a set of secants of an observable information portrait is offered. The virtual portrait (VP) states of nonlinear system of identification in special structural space are introduced. The method of decision-making on a class of nonlinear functions based on the analysis of properties VP is developed. The method of identification of a nonlinear part of object on based on the construction of sector, which belongs to nonlinearity is described. Results of modelling have confirmed the working capacity of the offered methods and algorithms.

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